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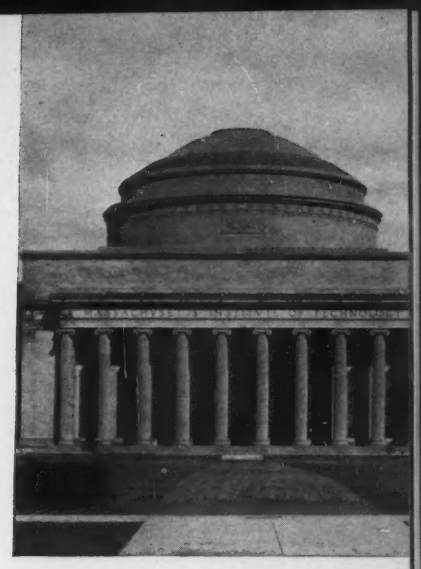

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HENRY J. OGORZALY
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ZAY B. CURTIS, Jr.
Editor-in-Chief

JAMES D. PARKER
Business Manager

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The Sportsman

MOLTEN WATER

PROBLEMS OF THE CHEMICAL ENGINEER

By ***WALTER G. WHITMAN '17***
Head of the Chemical Engineering Department
Massachusetts Institute of Technology

HORIZONS FOR THE CHEMICAL ENGINEER

THE chemical industries can be defined as those which change the structure of their raw materials in the processes of transforming them into finished products, in contradistinction to the mechanical industries, which in general change form but not structure. Thus defined, of the manufacturing industries of the country, excluding agriculture, some 60 per cent., measured in value of product, are chemical. These industries can be directed successfully only by engineers who are masters of the chemistry which underlies their fundamental transformations of materials. Their magnitude is in itself a guarantee of breadth of opportunity to men adequately trained in the chemical principles upon which their operations depend.

The promise of future opportunity for such men seems even greater. Thus, despite the present oversupply, there is reason to fear a shortage of petroleum in this country in a not distant future. The solution of the problem is already available in the hydrogenation of coal, but this development will require the creation of a new chemical industry of the first magnitude. Despite the expansion in the manufacture of rayon during the last decade, analysis of the situation indicates no likelihood of reduction in rate of growth of the industry in the immediate future. The cotton planter is disturbed at the danger of losing his foreign market, but does not sense the risk of having no market at all, owing to the inroads of chemically synthesized fibers. Improvements in the cultivation of rubber promise large reductions in cost of this vital raw material, which cannot fail to result in expansion of that industry into fields in which it has hitherto been unable to compete. Meanwhile, cheap, chemically synthesized rubber seems just over the horizon. Its advent will require the creation of a new chemical industry, which in turn will still further spur the development of the old one. Since the turn of the century, improvements in the quality and production of other types of plastics have been even greater than those in rubber, but the rate of development is still on a high level and shows no indication of decrease. The cement and the paint of today are unsatisfactory for the construction of tomorrow. The soap which, without change in composition and character, has served our needs for almost two centuries is being replaced by new and better synthetically prepared detergents. The rate of expansion of the chemical industry is apparently higher today than the average of industry as a whole, and promises to remain so, at least for the years immediately ahead.

Despite the expanding demand for chemical engineers, the opportunity for mediocrity in this field is probably less than elsewhere. The work is not standardized. It requires initiative, resourcefulness, creativity. The man lacking these qualifications is squeezed out by the competition. The man possessing them finds the larger opportunity for usefulness and achievement.

WARREN K. LEWIS,
Professor of Chemical Engineering.

MOST practicing chemical engineers are probably curious to know just how chemical engineering should be defined and wherein its limitations lie. The variety of the duties performed by these men seems to defy any attempt to demark their profession sharply, save that they are usually found in industries where chemistry is a significant factor. Actually, the chemical engineer shares with engineers of other branches the common characteristic that his abilities may be called into play along lines only distantly related to his professional course, but where the application of the scientific method is vital to accomplishment. His technical worth is determined largely by his ability to apply clear thinking to the solution of new questions.

There are, however, certain classes of problems which are so frequently encountered by the chemical engineer that they may be regarded as typical of one phase of his activity. One of these will be presented in some detail to show the breadth of interest and of judgment which he must be prepared to exercise in conjunction with the application of his technology.

Suppose, for instance, that a new process, converting a cheap by-product into a material selling at a much higher price, has been discovered by laboratory experiments, which indicate the yields obtainable under several operating conditions. Can this process be adapted to successful commercial operation? If so, along what lines should the development proceed?

Questions of this type are simple to propound and almost always difficult to answer. The proper solution demands not only the use of detailed technical knowledge and experience, but also a comprehensive appreciation of the effects which the proposed process might have on other processes in the plant and on such factors as the supply and cost of raw materials and the extent and availability of markets. Probably no one individual will have all the data necessary for the solution in his own hands, and the co-operation of research, processing, engineering, and marketing departments may be essential. In such an event, the ability to secure co-operation from these several departments and to weigh properly the information which they contribute will largely determine whether a correct answer is secured. It is obvious that, although many people may be involved in the complete analysis, one man must be responsible for correlating all the separate features and fitting them into a unified plan.

The initial move is usually to determine whether the process can be carried out on a commercial scale under any conditions within reason. This is merely a preliminary step, to decide whether further work is justified. It involves laying out a rough flow diagram, indicating the types of equipment which might prove suitable, the quantities involved throughout the process, and approximate values of temperatures, pressures, and concentrations. Probably certain major questions will at once appear. For example, the laboratory experiments may have been carried on at high temperature in quartz

tubes, whereas quartz would prove prohibitively expensive on a commercial scale. The possibility of using steel or an alloy will then be suggested to the laboratory investigator for experiment. Perhaps the by-product available as raw material will be somewhat changed in character because of the effect of the new process on other plant operations, requiring that experiments be made using a somewhat modified raw material. Again, certain arbitrary conditions employed in the experimental procedure may prove quite unadapted to commercial operation, as indicated by the equipment on the flow diagram, and new conditions must be investigated.

If this initial move shows that a reasonable manufacturing operation can probably be realized, the next step is to visualize the complete problem, outlining every move in the process from raw material to the sale of the finished product and considering any indirect effect of the new process on other operations. The primary object at this point is to determine what features of the problem are significantly uncertain and, therefore, require detailed study. For example, the price assigned to the by-product which is to be used as raw material may be a purely arbitrary accounting figure; its legitimacy for the purpose at hand must be critically examined. A more careful analysis of the processing operation may uncover further difficulties which had previously been overlooked and which require additional laboratory work. Perhaps the present market for the proposed product would be flooded by only a fraction of the possible output; a market analysis must be made to indicate the probable prices which would be secured at various levels of production. Many questions of similar character will develop and a plan of attack must be organized for solving them. Competent planning of work is particularly necessary at this stage if the program is to be balanced so that the task can be completed with speed and efficiency.

At this point it is usually wise to estimate the final answer to the problem, filling in all factors such as material, plant and operating costs, yields, and product realizations by rough estimates based on experience. This is done primarily to insure that all important items have been considered and to bring to the work a sense of proportion which will indicate what accuracy is necessary in the component parts. The preliminary estimates may, of course, indicate that the whole proposition is economically futile, but unless the engineer is very certain of such a conclusion, he had best lose this rough estimate in some unused drawer of his desk in order to avoid bias when later figures of greater accuracy are available for consideration.

Now that the work of other departments has been mapped out and initiated, the chemical engineer is ready to consider the plant process more specifically. This is a tremendously important step if the investment in equipment and the manufacturing costs are a significant phase of the problem, and makes the utmost demands upon skill, experience, and imagination. For example, if he fails to appreciate that for this particular case a continuous process would be preferable to a batch process, or if he does not realize that other possible operating conditions should be much superior to those which were employed in the laboratory experiments, there is a great probability that these points will be overlooked in the later work on details.

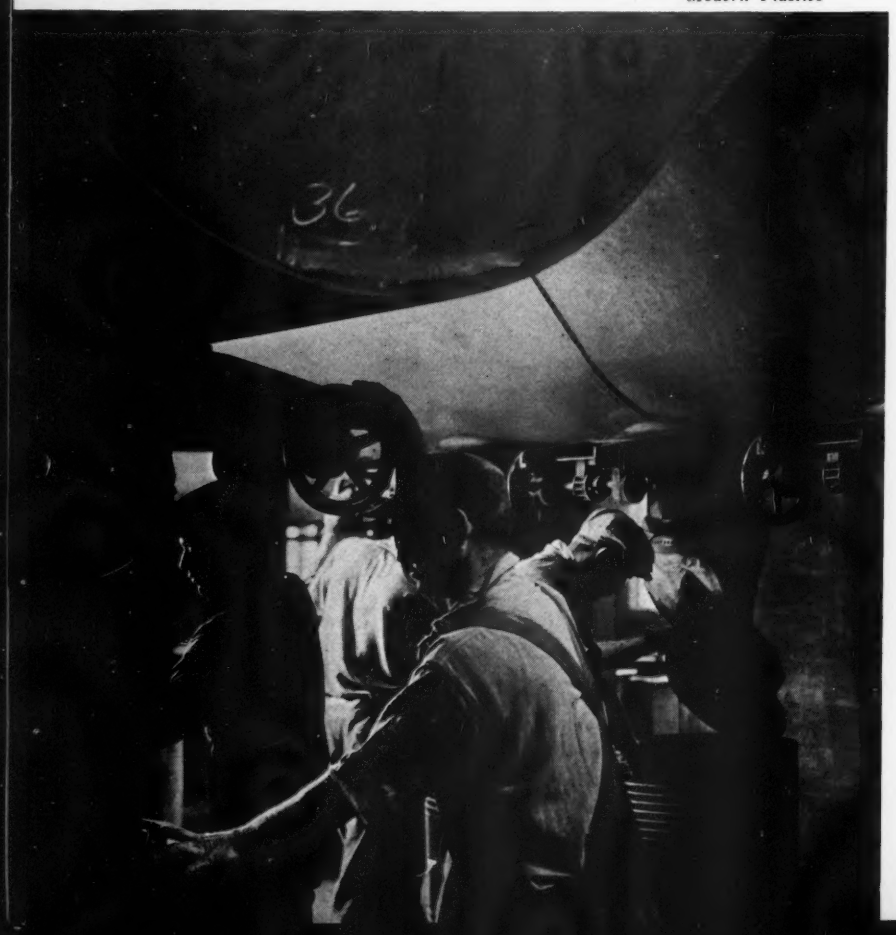
A reasonable process has now been laid out. The next step is to put it in shape for an estimate of investment and operating costs. At once the engineer faces the necessity of deciding between numerous options, both in the method of operation and in the specific equipment to be employed. At one point the cost of a heat exchanger must be balanced against the savings in fuel expense and in size of furnace which it may permit. At another, the extra cost of higher pressure operations, perhaps in both equipment and pumping expenses, must be balanced against the greater yield of product which may be attainable at higher pressure. At still another, the cost of conveying equipment must be compared with the labor cost for manual performance of the same operation.

These comparisons are all classifiable under the general designation of economic balance, and a sound technical background plus the imagination to see its application are indispensable. It will be noted that balance of investment against operating costs are universally spread throughout this work. How should these two be compared, that is, what payoff time should be expected on additional investment in equipment?

This is one of the broadest questions involved in the whole analysis, although it may not be the most important. In answering it, another recapitulation of the whole proposition should be made, using any additional data which have become available, in order to determine the probable safety of the investment which the process will entail. If the proposition now appears to be highly speculative, investment expenses should be kept to a minimum. Conversely, a fair assurance of profitable operation for a long period would justify the engineer in spending more for equipment in order to save operating costs. As an illustration, the economic balance might be based on paying off extra equipment costs by operating savings in from one to one and a half years for the former case and in three to four years for the latter. The folly of counting on longer payoff times, particularly with processes in the chemical industry, has been adequately demonstrated during the recent depression.

The size of the plant to be constructed will

Modern Plastics



usually have a dominant effect on the investment and operating costs per unit of product. Labor for a unit of large capacity is often only a little more than that necessary on a smaller unit, and the costs of equipment hardly ever increase in proportion as size is increased. In practice it is often necessary to carry through several designs at different capacities, estimating investment and operating costs on each, and deferring the decision between them until all available factors on the raw material and marketing situations have been secured.

In preparing these estimates of investment and operating costs, it should not be assumed that close accuracy is yet in order. The delay and expense of careful estimates are too great to be justified at this stage of the program. Rather, the present function of the engineer is to determine with fair probability whether the prospects warrant actual design work and decisions on details.

A complete flow sheet showing quantities of all materials and the types and approximate size of equipment is now developed and refined by persistent use of the economic balance of equipment against operating costs. If the process is such that yields can be varied by modifying the processing conditions, the economic balance must necessarily indicate raw materials as an item in operating expense. Where the optional processing methods available to the engineer entail differences in total production and the market can absorb the maximum output with more net profit than can be obtained from any smaller amount of product, the economic balance should be based on anticipated profits rather than on costs.

In all this work, a fine sense of proportion, often regarded as the engineer's most useful asset, is invaluable. Time spent in careful calculation on an exchanger which will cost only $5000 but which will be used in a plant costing perhaps $500,000 is obviously wasted. Arguments over whether seven men are necessary on a shift or whether the number might possibly be reduced to five are lost motion if the probable uncertainty in some factor such as the true cost of the raw material is greatly in excess of the labor cost for the two workmen at issue. Speed is almost always at a premium, and quibbles over minor details are futile when some major uncertainty may be demanding further investigation.

With the data from further laboratory experiments, the design of the plant, the marketing analysis, and other relevant factors now available, the basis for reaching a decision has been secured and the complete picture can be drawn in more detail. While the collaboration of several departments may have been utilized, it is always necessary that one man have a comprehensive view of the proposition in its entirety, inserting each new item of information as it is received in its proper place and determining whether it is sufficiently accurate for the requirements of the problem. The chemical engineer, because of the breadth of his training, should be competent to serve as the leader in this work of correlating the dissimilar elements of laboratory research, engineering, operating experience, and sales predictions. He now prepares a final analysis covering all essentials, and discusses this with his several collaborators in other departments to check the applicability of his use of their material.

This brings him to the point of making the decision as to whether the proposition should be abandoned, whether a full-scale plant should be constructed, or whether a pilot plant is advisable, a decision which must

Modern Plastic

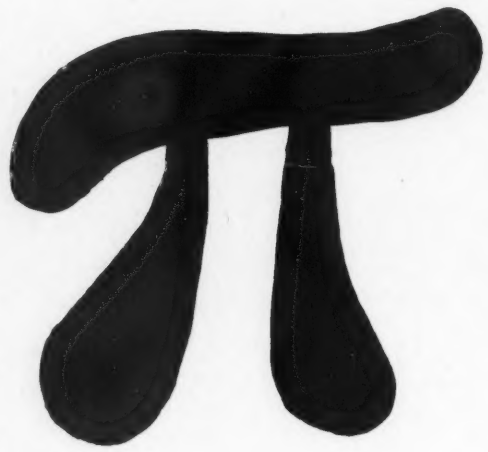
be reached from as broad, as unbiased, and as critical a point of view as is possible.

Existing conditions may make immediate construction inadvisable, and yet a probable future price trend may completely alter the situation. In such an event, he must decide whether the proposition justifies detailed design work, or whether the whole matter should be deferred until these price trends exhibit more definite signs of developing. Construction of a pilot plant may appeal to him as an advisable preliminary to building a commercial scale plant. Yet this plan often proves indefensible because of the comparatively high cost of a system which must be large enough to produce data pertinent to full-scale operation and yet is too small in capacity to bring in appreciable realizations from the sale of the product.

This problem is obviously one of business judgment on which the final decision will be made by the management, but the stature of the chemical engineer is gauged largely by his ability to reach a sound decision for consideration by them and to display courage in his convictions. The final step of presenting his recommendation to the management for action will in general prove difficult or easy according to his own attitude. Experience demonstrates that if the job is properly done, the engineer's most difficult task will be to make the necessary decision and convince himself of the proper course of action. If he can fairly and honestly do this, the chances for acceptance of his recommendation are excellent.

THE GREEKS HAD A LETTER FOR IT

By BEVERLY DUDLEY '35
Massachusetts Institute of Technology



TWO centuries ago Leonhard Euler could hardly have been expected to know that the Greeks had a name for it, but being one of the foremost minds of his time, he did perceive, at any rate, that the Greeks had a letter for it, and appropriated the letter for his own particular use. "It" was the transcendental constant, 3.14159 . . . representing the ratio of the circumference to the diameter of a circle, and the letter for "it" which Euler chose was π. What "it" was called prior to Euler's appropriation is somewhat a matter for conjecture, but since even those whose mathematieal and engineering training is decidedly limited recognize the significance of π, we may conclude that, fortunately, Euler must have had a good publicity agent.

The methods used in the determination of a numerical value for π are of interest because of the considerable amount of time and effort expended on the problem of squaring the circle (*i.e.* constructing a square whose area is exactly equal to that of a given circle), but more important than this is that the methods used in the evaluation of π give a clear insight into the mathematical ideas in use at various times, and therefore provide us with a brief amount of mathematical history.

Attempts at the evaluation of π have fallen into three distinct periods, each of which is characterized by fundamentally different methods of attack. The first period, from antiquity to the invention of the calculus by Newton and Leibnitz, may be thought of as the geometrical period, in which the value of π was believed to be obtainable by geometrical constructions and during which it was believed that π was a rational number. The second period, lasting from the middle of the seventeenth century to the middle of the eighteenth century, was characterized by the use of convergent series and continued fractions. While these methods enabled a more accurate value of π to be determined, little new information was added during this period. The third period of the problem, which lasted until the beginning of the twentieth century, resulted in the determination of the irrationality of π. This article will be concerned, largely, with the first period.

Among the earliest records available concerning π are those connected with the ancient Hebrews and Babylonians. These peoples used the integer 3 for π, and while it may have been recognized that this value was not entirely correct, it appears that the approximation was sufficiently accurate for most purposes of antiquity. A few simple measurements with a tape measure and a slide rule calculation would have indicated to these ancients that the value is more nearly 3.14, but a procedure so obviously simple as this was impossible for them to follow, for these early people had, as yet, no conception of fractions—let alone decimals—and the logarithms upon which the operation of the slide rule is based were not discovered until centuries later.

In a papyrus manuscript copied from the original as early as 1700 B. C. it is stated that the area of a circle equals $(8d/9)^2$, which on substitution in the equation, $A = \pi d^2/4$, gives for π the value 3.1604. It appears that this value was obtained empirically since no account has been found of the method by which the equation was derived. Although it is not definitely known how far back this equation may be traced, it is certain, at any rate, that as early as 1700 B. C. the Egyptians were acquainted with fractions and powers. The Egyptian value of π, which is considerably more accurate than the integer 3, may have been derived as a result of the necessity of having accurate methods of surveying after the periodic inundations of the Nile. It appears that the early Egyptians were well ahead of their contemporaries, both in surveying as well as in mathematics.

The first real systematic attack on the determination of π was made by the Greek geometers, Antiphon and Bryson, who were contemporaries of Socrates, and later by Archimedes. The first of these geometers inscribed a square in a circle and thought that by successive divisions of the sides of the square, a polygon would ultimately be obtained, the sides of which would coincide with the circumference of the circle. The fact that this procedure would give only an approximation to the true value was not, apparently, appreciated by Antiphon. The method was improved by Bryson, who used circumscribed as well as inscribed polygons, although he, too, apparently failed to appreciate that this procedure could never lead to exact results.

In his work on the measurement of the circle, Archimedes proves the three theorems:

> (1) The area of any circle is equal to that of a right-angled triangle in which one of the sides about the right angle is equal to the radius and the other equal to the circumference of the circle.
>
> (2) The area of the circle is to the area of any square on its diameter as 11 is to 14.
>
> (3) The ratio of the circumference of any circle to its diameter is less than 3 1/7, but more than 3 10/71.

If we let r be the radius of the circle or half the side of the square, Archimedes' second theorem gives the ratio of the area of the circle to the area of the square as $(\pi r^2/4r^2) = 11/14$, which gives for the value of π the

repeating decimal 3.14285714 . . . . The third theorem gives the value of π as lying between the limits of 3.14285714 . . . and 3.14084507 . . . with a mean value of 3.141851 . . . , which is a fairly good approximation and sufficiently accurate for many purposes.

The method used by Archimedes was essentially one of circumscribing and inscribing a circle with polygons of an ever increasing number of sides, and determining the perimeters and diameters of these polygons as the number of sides increased—a method which is, in many ways, similar to modern methods of analysis. The difficulties with which Archimedes had to contend in determining an approximation for π can better be realized when it is appreciated that one of modern mathematics' greatest simplifications, that of Arabic notation for integers, was unknown to the early Greeks. Instead of the Arabic notation system, the Greeks used the letters of their alphabet together with primes or accent marks and similar other notation. The system of combining the various accented letters was similar to the Roman scheme in which addition was indicated if the smaller integer followed a larger, and subtraction was indicated if the smaller integer preceded the larger. The immature state of arithmetic at that time was the only real obstacle preventing π from being calculated to any desired degree of accuracy.

It may, therefore, be seen that the Greeks not only provided a symbol for one of the most useful constants in mathematics, but were also responsible for the first systematic attack on the problem of obtaining a numerical value for the constant.

With the decline of Greece, mathematics gained its greatest following in India, for the Romans, who occupied the political stage of Europe after the Greeks, had no use for a subject as abstract and remote from politics as mathematics and consequently contributed nothing to its development. The early Hindoos employed the value 3 for π and later the value, $\pi = \sqrt{10}$. It has been suggested that this value may have been obtained as the supposed limit of the ratio of the perimeter to the distance between opposite sides of a polygon as the number of sides became infinitely great. This suggestion appears reasonable when it is appreciated that, taking 10 as the radius of a circle, the perimeters of polygons of 12, 24, 48, and 96 sides, may be expressed, respectively, by the numbers $\sqrt{965}$, $\sqrt{981}$, $\sqrt{986}$, $\sqrt{986+}$. The error in this conclusion is that the limit is not $\sqrt{1000}$, as was supposed, but $\sqrt{986.96044}$.

As early as the 12th century B. C. Chinese mathematicians employed the value $\pi = 3$. The value $\pi = \sqrt{10}$ was used in China about the middle of the second century A. D. Later, the values 142/45 and 157/50, which are equivalent to the approximations 3.1555 . . . and 3.14000 respectively were in some use. The most interesting Chinese determination was that of the astronomer Tsu Ch'ung-chih (born 430 A. D.), who found the two values 22/7 and 355/113, the latter value being 3.1415929 . . . expressed decimally, and accurate to six significant figures.

To the quest for an evaluation of π the Arabs offered little or nothing of importance, although their contributions of the present number system is of inestimable value. Various Arabian mathematicians gave as the value of π the expressions, 22/7,$\sqrt{10}$, 62832/2000, and 3928/1250, the latter two expressions being accurate to five significant figures, although it appears doubtful that these determinations were obtained independently by the Arabs.

During the Renaissance much of the earlier mathematical work which had been done in Greece, India, China, and Arabia was taken up by the Europeans, who now began to dominate the field of mathematical thought. Adriaen Anthonisz (1527-1607) discovered the Chinese value 3.1415929 . . . , and his son published a work in which the value of π, using the method of exhaustion employed by Archimedes, was found to lie between 333/106 and 377/120. These last two fractions give the value for π as 3.1415094 . . . and 3.1416666 . . . . Applying the method used by Archimedes, Adrianus Romanus (1561-1615) calculated π to 15 places in 1593, and Ludolf van Ceulan (1539-1610) extended the value to 35 places. In Germany, π is sometimes spoken of as Ludolph's constant.

Using the method of Archimedes, Francois Viete (1540-1603) showed that the value of π lies between 3.1415926535 and 3.1415926537, a value which is correct to nine decimal places. Although chronologically Viete belongs to the first period, he anticipated the more advanced method of calculating π which was used in the second period, by being the first to obtain a value for π as a result of an infinite sequence of operations.

With the foundation of the differential calculus by Newton and Leibnitz, the ideas of mathematicians underwent radical changes which were reflected in the second period of this history of calculating π. During this second period the idea of a geometrical construction for π, which had dominated the thought of earlier mathematicians in earlier centuries, was replaced by other methods, most of them depending upon infinite series or continued fractions. Thus, from the time of Viete at least one series, and from the time of Newton and Leibnitz several series, were available for the calculation of π, so that a knowledge of geometry was no longer necessary for a determination of this important constant. But the second period contributed little besides providing methods of calculating π independent of geometry, notwithstanding the new mathematical methods available, and it remained for the mathematicians of the third period to conclude the problem.

(Continued on page 138)

3.14159	26535	89793	23846	26433	83279
50288	41971	69399	37510	58209	74944
59230	78164	06286	20899	86280	34825
34211	70679	82148	08651	32823	06647
09384	46095	50582	23172	53594	08128
48111	74502	84102	70193	85211	05559
64462	29489	54930	38196	44288	10675
66593	34461	28475	64823	37867	83165
27120	19091	45648	56692	34603	48610
49432	66482	13393	60226	02491	41273
72458	70066	06315	58817	48815	20920
96282	92540	91715	36436	78925	90360
01133	05354	88204	66521	38414	69519
41511	60943	30572	70365	75959	19530
92186	11738	19326	11793	10511	85480
74462	38798	34749	56735	18857	52724
89122	79381	83011	94912	98336	73362
44193	66430	86021	39501	60924	48077
23094	36285	53096	62027	55693	97986
95022	24749	96206	07497	03041	23669

—plus 107 more places

Pi as given in Shank's papers in the Proceedings of the Royal Society.

Solving Production Problems

WITH CONVEYERS

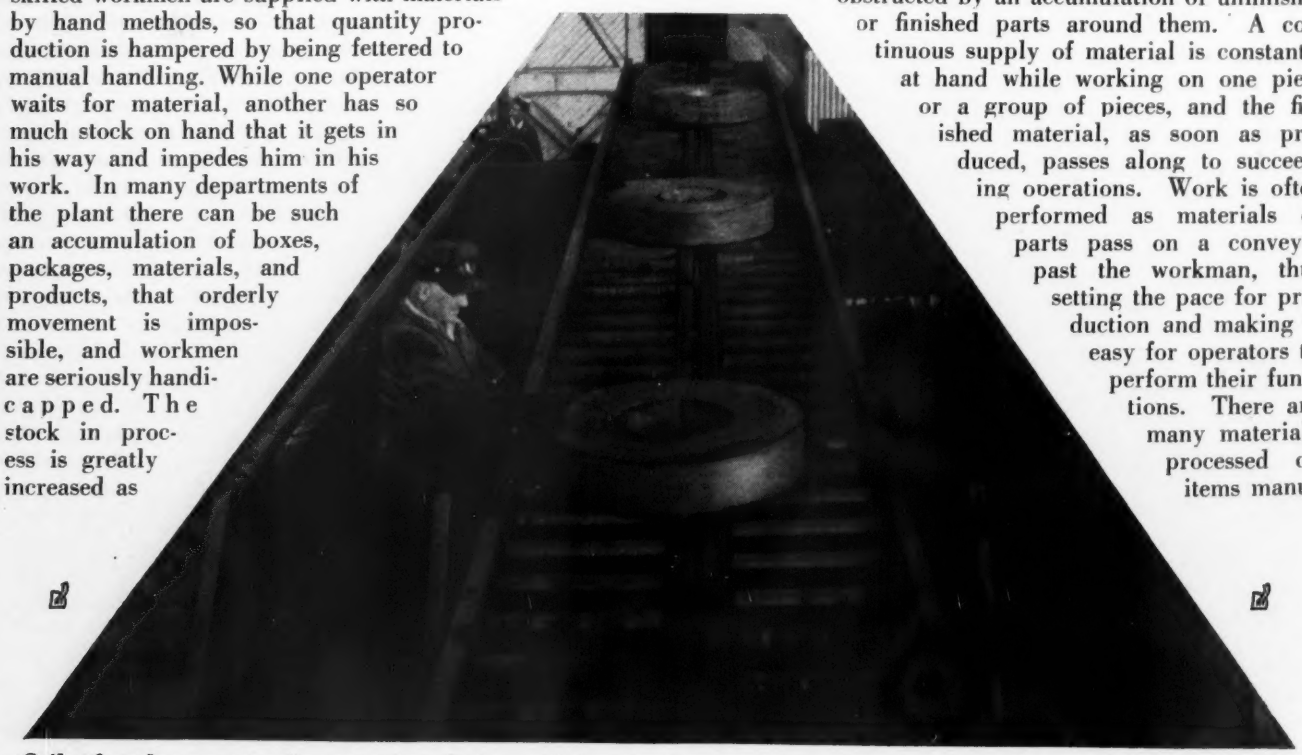
By M. J. ANDERSON
Chief Engineer
Matthews Conveyer Company

BECAUSE of present day economic conditions we hear and read much about the speed and progress in manufacturing that has been made possible by modern methods and equipment. Ever since James Watt, with the steam engine, gave the world a reliable source of power, engineers and inventors have devoted their energies to perfecting the products which we use and to developing better machinery and processes for manufacturing them. However, with the attention that has been given to the making of things mechanically, the question of moving things mechanically, though ranking in equal importance, has often been neglected and in many instances entirely overlooked.

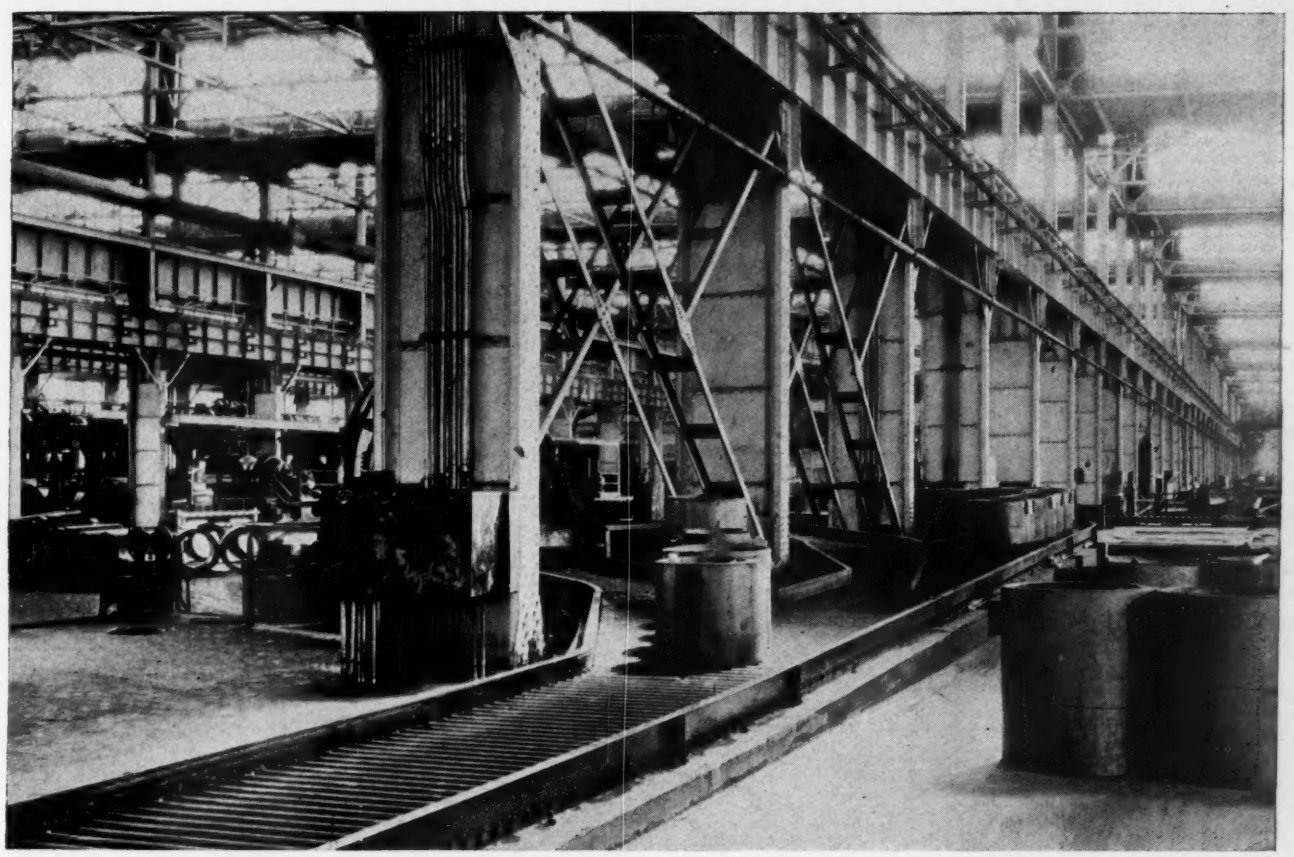
The leaks incidental in the routing of materials through a plant are often the source of the high costs that materially reduce the margin of profit and are the big stumbling blocks to well equipped and well managed concerns. Men are too often employed to move materials and products in and out of buildings and between departments and processes in industrial plants, where, with proper planning, mechanical methods could be used, thereby placing these men in more productive positions. The direct cost of the survival of hand methods in the handling and moving of materials is only a fractional part of the total cost. Much greater are the costs due to delays in production and delays in distribution of commodities in the process of manufacture, assembling and shipping, and in the extra space consumed by goods in process which are not kept moving. In many plants, costly machines tended by highly paid skilled workmen are supplied with materials by hand methods, so that quantity production is hampered by being fettered to manual handling. While one operator waits for material, another has so much stock on hand that it gets in his way and impedes him in his work. In many departments of the plant there can be such an accumulation of boxes, packages, materials, and products, that orderly movement is impossible, and workmen are seriously handicapped. The stock in process is greatly increased as quantities of materials pile up at each machine, or production unit, clogging the aisles and working space with parts in waiting that should be in work, thus tying up capital and sacrificing floor space.

Especially during periods of industrial activity, truckers cannot keep machines supplied with stock and maintain an even flow of material through the plant. Many of the difficulties in industry can be traced to obsolete handling methods, where conveyers would accomplish more at considerably less cost. This is one of the chief reasons why it is increasingly difficult to secure more production, why costs are rising, why the stock in process account is large, and why it is so difficult to rush through emergency orders. The great need in many plants is to put carrying and handling on a modern basis.

Many executives have recognized the value of conveyers for interior transportation and are classing them on the same footing as manufacturing processes, on a quantity production basis. Conveyers connect machines, processes, and departments, so that the product moves through the plant quickly, smoothly, and in logical order. Their application permits the routing of materials and containers without interruptions which break the regularity and therefore the momentum and efficiency of steady work. They save useless steps and bring about increased production with reduced expense. They are far more than carrying devices; they provide live storage and are often synchronized to processing operations or to machines. With the use of conveyers operators are not obliged to wait for material and are not obstructed by an accumulation of unfinished or finished parts around them. A continuous supply of material is constantly at hand while working on one piece or a group of pieces, and the finished material, as soon as produced, passes along to succeeding operations. Work is often performed as materials or parts pass on a conveyer past the workman, thus setting the pace for production and making it easy for operators to perform their functions. There are many materials processed or items manu-



Coils of steel are conveyed past a tying platform, discharging to a receiver conveyer in a vertical position pending removal.



Coils are conveyed from recoilers to annealing retorts on a gravity roller conveyer.

factured wherein the total cost is made up largely of machine labor and handling labor. Such a classification would cover a wide scope, ranging from very light manufactured parts, to fruit and vegetable handling, and to heavy foundry work. Present day practice can fit conveyers to practically all conditions, as to quantity, capacity, weight, and physical limitations of the plant and equipment. To get the best results it may be found necessary, in some cases, to rearrange machines or regroup operations.

In this day and age conveyers are serving in practically every class of industry, handling articles varying in weight from fractions of ounces, in the case of radio parts, to foundry molds weighing up to 10,000 pounds, or coils and stacks of steel strips or sheets weighing up to 40,000 pounds. Although steel mills are not as yet fully modernized, the writer has selected this subject because of the leadership this industry has shown in our industrial life.

An outline of the movement of materials in a continuous strip steel mill will serve to bring out how conveyers are utilized in the various processes. In the open-hearth building, where the ore and alloys are compounded, handling is mainly accomplished by means of industrial railways, cranes, and furnace charging machines. Even here, however, the modern mill has recognized the advantages of conveyers. Much firebrick is received, stored, and used for relining furnaces. For the handling of this brick from the cars to storage, and from storage to furnaces, gravity roller conveyers are used, working in conjunction with a portable and adjustable inclined brick elevating conveyer. This combination permits a flexibility in handling over a wide area and at various elevations. Portable sections of roller conveyer are connected at either or both ends of the portable elevating unit to permit receiving and delivering of brick for the convenience of the workmen.

Ingots weighing many tons are poured from large ladles filled from the open-hearth furnaces. These are cooled in their molds on suitable cars and delivered to the soaking-pit building, where the molds are removed. After the required heating period the ingots are delivered by crane from the soaking pits to the blooming mill, where they are slabbed down to required thickness for the continuous mill. Driven rollers supply the conveying means for ingots as well as for the slabs. From the blooming mill the slab continues on a roller table to the shear, where the slab ingots are cut to the required size for rolling.

At this point the sheared slabs are kicked out from the roller table to a cross conveyer usually of multiple strands of heavy chain. From the discharge of this chain conveyer the slabs slide onto a cross conveyer in front of the reheat furnaces. These furnaces supply slabs to the continuous mill in order as required and they are used as a bank between the blooming mill and the stands of the finishing mills. When reheated slabs are discharged from these furnaces, they slide from the furnace, which is at somewhat higher elevation, to the main mill delivery tables. These tables, as previously mentioned, are roller tables, the rollers in many cases being driven by individual motors.

A typical stand of mills would include ten mills, each one successively reducing the thickness of the plate. The maximum delivery speed at the last mill is around 1200 feet per minute, depending on the thickness of the sheet being rolled. When the strip shoots out on the roller table extending from the last mill, it has one of two destinations. If it is a strip of standard commercial

(Continued on page 136)

SUPPLYING BULLETS FOR THE VAN DE GRAAFF GUN

By GODWIN R. GAY '37
Massachusetts Institute of Technology

THE rapid strides which have been taken during the past decade in physical experimentation have been accompanied by a coincident increase in public interest. The public has changed its attitude from scorn to praise, mainly through the realization that many modern conveniences are the direct outcome of purely scientific experiment.

An apparatus which is nearing completion is the Van de Graaff generator, with which atomic disintegration experiments will be performed. Although much has been written about the generator itself, comparatively little has appeared concerning the manner in which the stupendous voltages produced by the machine will be utilized. If we consider the atom as a target, the generator may be likened to the gun which shoots a projectile; it is this projectile, the proton, with which this article deals. Dentons (denterium nuclei) may also be used, or even positively ionized heavier atoms as He, Li, or Hg.

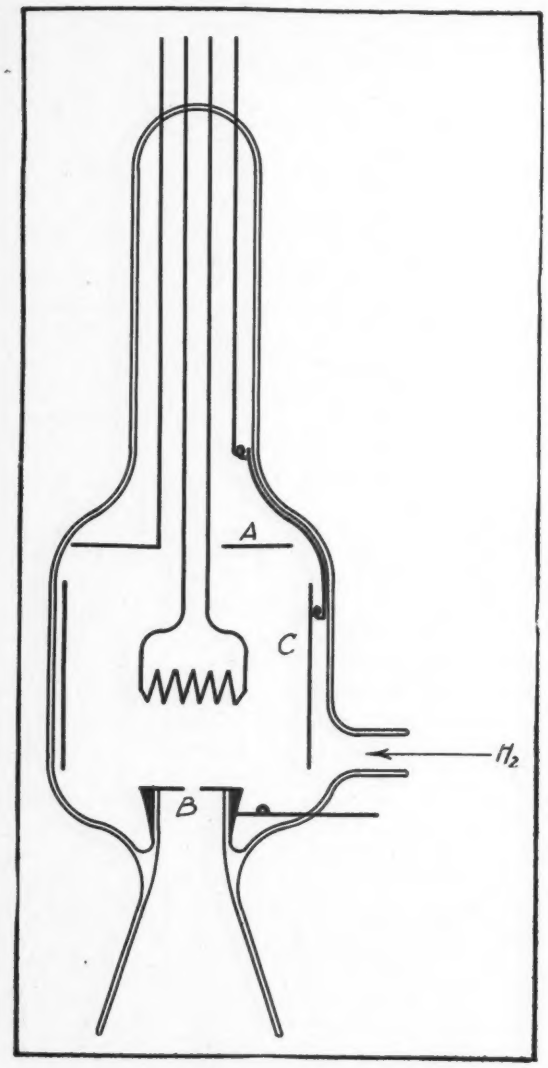


Fig. 1. The so-called "ion-gun". Hydrogen gas comes into the evacuated chamber as shown by arrow, becomes ionized, and streams out of B as protons and "ion molecules".

The proton, which is the most elementary positive particle,—with the possible exception of the recently discovered neutron and positive-electron, which may or may not be elementary particles, but are conveniently regarded as such until we know more about them,—is of great use in numerous sub-atomic researches, as, for example, in those experiments which lead to the disintegration of certain chemical elements into more elementary units.

It is, then, quite obvious that it is of the utmost importance to physical research that some method be devised to obtain an efficient source of protons. It might be well in an article of this sort to describe the way in which this was done prior to the new method devised at the Massachusetts Institute of Technology by O. Luhr and E. S. Lamar.

Luhr and Lamar have used an ingenious device which enabled them to obtain very high yields (90 per cent.) of protons with little difficulty. The hydrogen gas is first passed over heated copper to remove any oxygen present. It is then passed successively through tubes containing calcium chloride, potassium hydroxide, and phosphorus pentoxide, in order to remove moisture and carbon dioxide. Further precaution is taken by passing the gas through a tube surrounded by liquid air, which removes from the hydrogen all traces of moisture or chance impurities. The hydrogen then passes into the highly evacuated chamber shown in Fig. 1. The pressure in the tube is about .3 mm. of mercury or about 0.0004 atmospheres. The large oxide-coated filament emits an electron current of from two to three amperes. Between the filament and the nickel anode disc, A, is maintained a potential of thirty volts with a current of approximately one ampere, which is carried by the electrons. These electrons bombard the neutral atoms and molecules, knocking off electrons and thus ionizing the gas. Protons filter out through the small hole, B. Since this so-called "ion-gun" is part of a separate circuit, its potential may be varied in order to control the outlet of protons.

Their proton tube differs from the others by the insertion of a nickel cylinder, C, which is negative with respect to the filament. Between the two is maintained a potential of one hundred volts. Now let us consider what advantage this seemingly simple change possesses. The electrons still migrate to the anode disc, but the positive ions, instead of moving to the filament, are attracted largely to the nickel cylinder, where they form a "space charge sheath" about one mm. thick. It is evident that a large velocity is acquired by a positive ion when it pierces this "space charge sheath." When one does get through, it loses its charge, but not its velocity, that is, it bounces back from the metal walls into the chamber with great speed. These fast-moving neutral

particles, upon collision with hydrogen molecules, cause the latter to dissociate according to the equation:

$$H_2 = H + H$$

Electrons produce most if not all of the ionization. High speed neutrals produce only dissociation as shown above. The hydrogen becomes mostly atomic instead of molecular, and the protons speed out through B under the influence of the potential of the metal ring. In this way a large yield of protons is obtained. A beam of protons from this type of tube will be used as projectiles in the Van de Graaff experiments.

In order to draw a concentrated beam of protons, it is necessary that the lower part of the tube be even more highly evacuated than the chamber itself to avoid scathing by gas. This condition directly limits the size of the hole, B, because gas from source leaks through it and consequently the size of the whole tube. The full seven million volts from the Van de Graaff generator will be used to produce a field through which the protons will be shot The protons, accelerated by the field nearly to the velocity of light, will be aimed at a target containing atoms of the type to be disintegrated.

The apparatus used to measure the proton yield is no less interesting than that described above. In another guise this apparatus is the same spectrograph which is so important in the detection of isotopes of elements. A strong magnetic field is superimposed at right angles to the beam of protons. This field deflects the beam from its straight path to a semicircular arc, (Fig. 2). The protons impinge on plate MN. By careful adjusting of the field strength of the magnets, the particles may be made to pass through the slit and fall into the metal box, F. This so-called Faraday box is connected to a quadrant electrometer, which is an ingenious device used to measure currents as small as 10^{-14} amperes or even better. A diagram of the complete instrument is shown in Figs. 2 and 3. Inside and at the bottom of the brass cylinder is the actual meter. It consists of a hollow cylindrical shell of copper, one centimeter in diameter and .25 cm. high, divided into four quadrants, each of which is insulated from the others. Inside of this shell a vane of aluminum foil, .001 in. thick, is suspended by an extremely fine quartz thread. Opposite quadrants are electrically connected. One pair is grounded, while the other is connected to the Faraday box. When the vane itself is charged, since the quadrants are oppositely charged, the vane will rotate. A beam of light reflected from the mirror, A, upon a graduated ground glass scale makes it possible to measure the rate of deflection. For 10^{-14} amperes the latter is as much as 10 cm. per sec.

From the speed of the ions, the radius of curvature of the path, and the magnetic field producing the maximum rate of deflection, it is possible to calculate the mass of the particles falling into the Faraday box. The greater the mass of the particles, the greater must be the strength of the magnetic field in order to make them pass through the slit. The graphs of Fig. 4 show the relative amounts of protons to ion molecules produced by the Luhr and Lamar method as compared with older methods.

All parts of the electrometer must be carefully shielded from stray potentials which would deflect the sensitive vane crazily. It is interesting that most insulators for ordinary electric currents are useless for the type of current fed to the electrometer. It has been found that amber or sulfur serve as the best insulating materials.

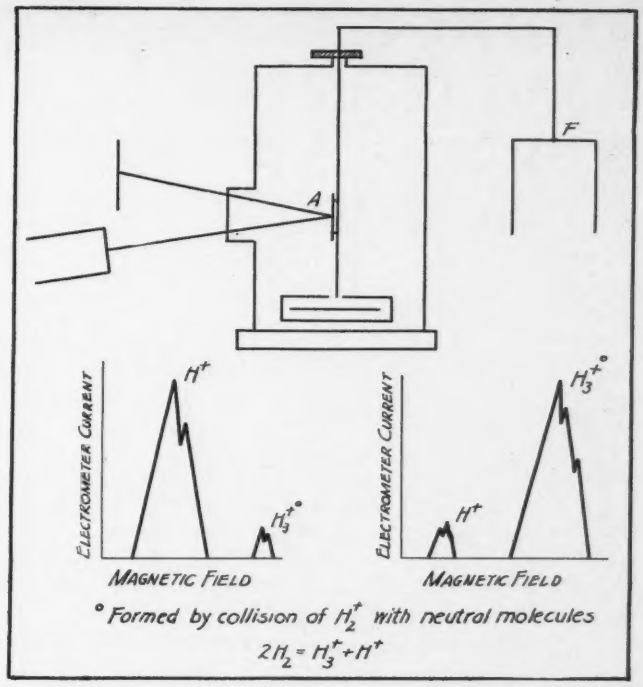


Fig. 3. Above: Side elevation diagram of the quadrant electrometer. Below: Graph showing relative amounts of protons to ion molecules produced by the Luhr and Lamar method as compared with older methods.

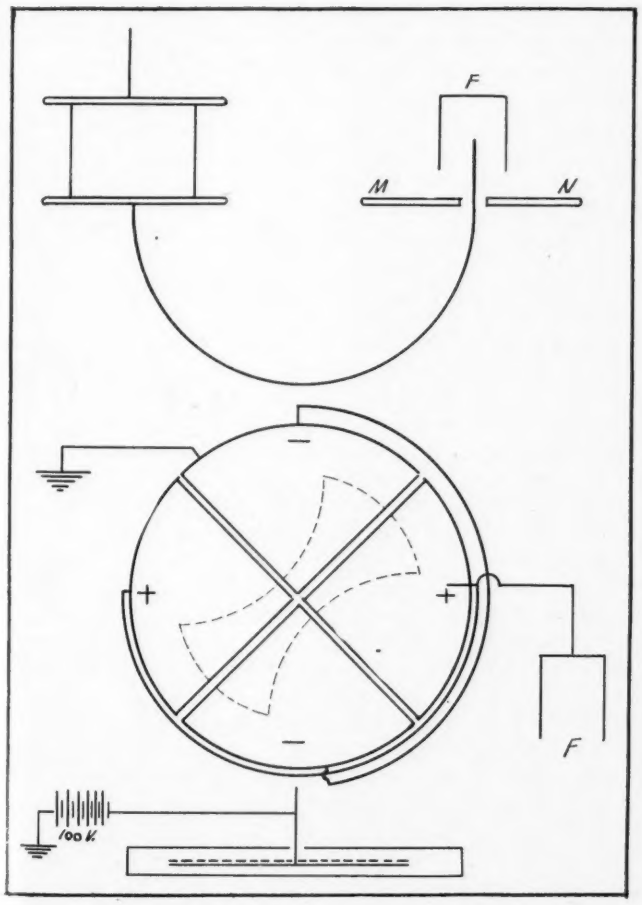


Fig. 2. Above: Semicircular path taken by protons in traveling to the Faraday box. Below: Plan view diagram of the quadrant electrometer.

THE TECH ENGINEERING NEWS

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EDITORIALS

ILLUMINATING ENGINEERING

WE are in the midst of startling advances in the art of lighting. Evidences are on every side: the soft yellow glow of the new sodium-vapor lamps illuminating our highways, the brilliant red and green of our constantly increasing multitude of advertising signs, the adequate lighting of rooms by luminous panels which are now designed as an integral part of the building—all point to the revolution which is taking place in the lighting art.

But it is generally felt that the education of the illuminating engineer has not kept pace with the recent progress of the industry. The lamp companies and the public utilities find that most electrical engineering graduates, though excellently trained in their field, are entirely ignorant of architecture, color, and the fundamentals of vision, a knowledge of which is so essential to the illuminating engineer. Even the introduction of lighting subjects in the fourth or fifth year of a college course appears to be unsatisfactory. Evidently, what is needed is an entirely new course, not based exclusively on engineering or on art or on business, but designed of a combination of these elements to fit men specifically for this complex field which we call illuminating engineering.

To meet such a need, a new course of study has been introduced this year at Technology. Incidentally, this is the first four-year course in illuminating engineering in the United States. The curriculum is basically much like that of Course VI; but work in architecture and color begins in the second year and continues through the remainder of the course, in parallel with the engineering study of light sources and the calculation of illumination. The details are the result of numerous conferences with Professor Jackson, Professor Hudson, Dean Emerson, and others. Many valuable suggestions received from the lighting industry have also been incorporated.

A description of the course was sent to about thirty leaders in the lighting profession, and the interest shown, as evidenced by the very careful and detailed comments and criticisms, was extremely gratifying. The number of graduates of an illuminating course which can be absorbed by the industry per year under ordinary conditions, assuming no growth of illuminating engineering in the future, was variously estimated from 1 to 300, but the average was 76, not far from the Illuminating Engineering Society's estimate of 60. Though the field of illuminating engineering is thus much smaller than the field of electrical engineering, many feel that at present it offers better possibilities because it is less overcrowded.

PARRY MOON,
Assistant Professor of Electrical Engineering.

RESEARCH IN REVIEW

COURSE I — Civil Engineering

FOR the past year Dr. Gilboy and his assistants have been considering the problem of determining the elastic constants in soils of different characters. Up to the present, most of the time has been devoted to the development of the equipment needed for the research program.

Several other problems under investigation by Dr. Gilboy and his students are the determination of the laws which state the characteristics of the flow of water through embankments on pervious foundations, and the laws which state the characteristics of the flow of water toward well-points and test pits. A considerable amount of attention is being given to an attempt to discover the laws which state the variation of the pressure intensity under footings in walls and buildings.

Mr. Ruge has spent much of the past year on the investigation, through the use of models, of the behavior of water tank towers during earthquakes, and is studying possible changes in standard methods of design in order to improve greatly the stability of the towers under earthquake conditions. As part of his problem he has found it necessary to design a shaking table which provides vibrations of any character desired.

During the past two years an investigation has been conducted under the direction of Professor C. B. Breed of the annual road costs on certain Massachusetts state highways to develop a practical method of evaluating road costs, and presenting them in such a manner as to be of value to the highway engineer in economically planning highway improvement.

Certain research is now in progress to determine the effect of many important properties such as the chemical composition of the cement, and the chemical and physical character of the aggregate, upon the compressive strength, heat of hydration, drying shrinkage, and durability of concrete. Other research is expected to reveal something of the physical and chemical structure of the hydration products of cement. The ultimate aim is to determine how best to secure concrete which not only has sufficient strength, but is durable and has minimum change in volume after it is cast.

A new analyzing device which is being developed has to do with temperatures in concrete. As cement combines with water during the hardening period, which may extend for many months or even years, heat is generated which causes the concrete to rise in temperature, especially when cast in large masses. The volume changes which result are the cause of many cracks which form, and therefore the heat generation is important. The calculation of the temperature distribution which will develop in concrete is extremely difficult because the rate of heat liberation does not vary in a simple manner and the concrete is cast neither instantaneously nor at a uniform rate. In attempting a mathematical solution, the differential equations which result are impracticable of solution and an approximate method of "finite differences" is usually resorted to. The new analyzing device makes use of the analogy between the flow of a fluid and the conduction of heat. It consists of a series of columns connected by capillary tubes. The height of fluid in a column represents the temperature of a section of the concrete and the amount of fluid represents the quantity of stored heat. The time scale can be computed from the various dimensions and the viscosity of the fluid. Usually, the results of an hour on this device correspond to several days in the concrete.

COURSE VII — Biology and Public Health

THE research projects in the field of Biology and Public Health include a wide scope of highly varied problems. A study of the plants and animals from one small pond in Milton has yielded to date 225 different plants and 335 animals, several of which are previously undescribed in this region. Co-operative investigations in the upper air with the Division of Meteorology have resulted in finding bacteria up in the clouds more than four miles. Analytical studies of the movement of certain parts of animal organisms have been carried out with favorable results, using the stroboscopic photographic apparatus for those movements too rapid for other means of measurement. An extensive investigation is being made of the fundamental chemical principles concerned in the loss of flavor and staling of coffee under certain conditions of storage. In the vitamin laboratories the experimentation concerning the curative values of foods in certain deficiency diseases and the relation of light irradiation has been continued and amplified.

The public health research has been directed particularly to include the consideration of those tests which are used in determining the purity and safety of water supplies. A part of this work has been a co-operative project in connection with the American Public Health Association and with several other universities. Biological studies are also under way which involve the fauna and flora of rapid sand filters, such as many municipalities use for purifying their water supplies.

The health education research activities embrace a study of certain phases of tuberculosis, which were recently published, and a continuation of the evaluation of the health education procedures and techniques in the Malden school system. This work, started in Malden a few years ago under the auspices of this department, is the model for many American school health systems now.

Research in industrial hygiene includes a survey, analysis, and evaluation of vocational tests used in the selection of industrial workers. Data are also being collected and analyzed to determine the effectiveness, scope, and cost of various health activities in industry.

An investigation of the biochemical activities of some of the lower fungi is in progress; another is concerned with the growth activities of certain pathogenic fungi. A fellowship recently granted has made possible the continuation of studies on germicides and antiseptics. One of the Textile Foundation fellowships has resulted in definite knowledge concerning the microbic populations of textiles and their intimate relation to certain kinds of fiber deterioration.

The effect of low temperatures on bacteria and research concerning those types of bacteria which are asso-

(Continued on page 140)

ENGINEERING DIGEST

TELEVISION

ACCORDING to a comprehensive survey of the television field undertaken by *Electronics*, television is here, and is ready for the public, so far as receiver technique is concerned. The transmission situation is blocked only by financial obstacles. The survey discloses that there are three classes of systems being developed. They are, in the order of their complexity, the mechanical systems, the light valve projector systems, and the cathode ray systems. Because of the gratifying results recently obtained, the cathode ray system is of particular interest at this time.

Of the cathode ray transmitters there are two major types: the "iconoscope" (RCA-Victor); and the "image dissector" (Television Laboratories). The iconoscope consists principally of an electron gun (cathode ray tube) which plays a stream of electrons on a specially prepared photo-sensitive mosaic, which is composed of millions of tiny separate particles. This mosaic is backed by a mica sheet, behind which is a metal coating, known as a signal plate. Each elemental droplet of the mosaic and this signal plate act as the two plates of a condenser, so that the net result is a great number of tiny individual condensers—all having one common plate. When an image is focussed on the photo-sensitive plate, each particle of the mosaic becomes a condenser whose charge is proportional to the amount of light which strikes it. These tiny condensers are successively discharged by the magnetically controlled stream of electrons, which scans the entire plate 24 times per second, dividing it into 300 lines each time. Each successive discharge is amplified and utilized as a television signal. The iconoscope was developed by V. K. Zworykin.

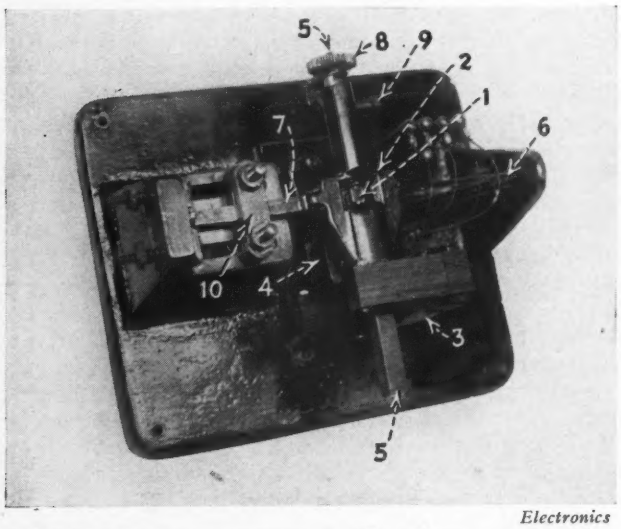
P. T. Farnesworth (Television Laboratories) has developed another form of cathode ray scanner which is called the "image dissector." In this instrument the scene to be televised is focussed on a photo-sensitive plate. Under the influence of the light, each point on the plate emits electrons, the number of electrons emitted in a given time being proportional to the brilliance of that point in the optical image. Thus, the optical image is really transformed into an electronic picture, the electrons of which are attracted to the positive anode at the other end of the tube. There, the entire electronic image is scanned across a small square aperture. The electrons which pass through this window are successively multiplied and amplified and used as television signals. This system also gives 24-three hundred line images per second.

Electronics

Studio technique, as practiced by engineers of the Philco Radio and Television Corporation. The operator has constant visual and aural check on the proceedings.

The three major exponents of the cathode ray systems (RCA-Victor, Philco, and Television Laboratories) now all use receivers which differ from each other only in minor aspects. They usually consist of a cathode ray tube whose electron beam is modulated in intensity by a control grid in accordance with the television signal received. Outside the tube are magnetic fields, which cause the modulated beam to deflect, in a horizontal direction for the lines, and in a vertical direction for image repetition. The beam is focussed on a fluorescent screen, which makes the image visible.

The other systems, although much more complicated, have in many cases shown promising results. It is interesting to note that the old scanning disk, consisting of spirally arranged holes, has entirely disappeared from the modern television field. (*Electronics*, vol. 7, no. 10, October, 1934.)—F. B. K.



Electronics

The Preiss resonant scanner: 1. The mirror. 2. Line frequency magnet. 3. Frame frequency magnet. 4. Polarizing coil. 5. Line frequency tortional rod. 6. Frame frequency tortional rod. 7. Control for frame frequency. 8. Adjustment for line frequency. 9. Lock for setting line frequency. 10. Lock for setting frame frequency.

STABILITY

TO the layman the loading of a ship with its cargo is a comparatively simple matter. A few considerations of trim, securing it against shifting, and protection against sweating and other dampness would seem to be sufficient. To the ship master, however, there is another

matter that must be very carefully watched—that of stability. The stability of a vessel is its ability to remain upright, or nearly so, under any conditions that it is likely to meet in service. It does not mean that the ship must be absolutely without motion due to the waves, but rather that it should have a slow and easy motion without the least danger of the ship capsizing. In general, for any particular ship there is the center of gravity, which is movable, and the metacenter, a theoretical point that is determined by the characteristics of the given hull under different conditions. The stability is determined by the distance between these two points, and the center of gravity must be below the metacenter if the ship is to remain upright. Thus, the ship master must know this distance if he is to be sure that his ship is properly loaded. Up to recently, this distance has been determined by approximations and expensive inclining experiments which are, to say the least, unsafe, costly, and inconvenient. Recently, however, there has been placed in use a device that will automatically record the metacentric height, as this distance is called at any given load condition. The instrument, called the Wilson Stability Meter, reads a result directly in feet and inches after the machine has been set to a constant of operation which is determined by calculations made by the marine engineer.

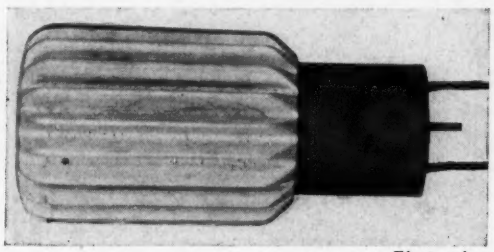
It can be proved mathematically that the metacentric height is dependent upon the maximum angle of roll at any instant and the maximum angular velocity reached during that roll. These effects are detected by a small damped pendulum and a small high-speed gyroscope respectively. The two movements thus obtained are transmitted to a pair of logarithmic slide rules by electrical devices and thence to the dial.

With this machine it is possible to eliminate much ballast which was formerly used as a factor of safety; and, by making the determination of stability an accurate process, the speed of the useful cargo that may be carried will be greatly increased. (*Marine Engineering and Shipping Age*, November, 1934.)—S. C. P.

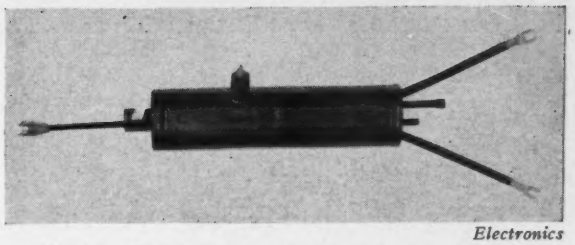
ALL METAL VACUUM TUBES

THE "all metal" vacuum tube, now being developed for industrial and power purposes, is a revolutionary improvement over the fragile, complicated and expensive glass tubes now in use. Metal tubes will be more sturdy than glass, will occupy less space, and are more easily cooled and mounted.

Three fundamental developments have made possible the adaptation of metal envelopes to vacuum tubes. (1) A sturdy type of seal with same expansion as insulator, (2) accurately controlled seam, spot, and projection welding for the fabrication of the actual envelope, (3) a vacuum-tight means of sealing off a metal exhaust tubulation, and many other recent developments have made possible metal tubes that are not only sturdier, smaller, and even longer lived than glass tubes, but also seem



Electronics



Electronics

Shield-grid Thyratron (3-element gas rectifier).

especially adapted to quantity production at low cost.

Thyratron controlled timing of resistance welds has made possible new types of welds with materials previously unsuitable, and has insured the reproducibility of any weld. One of the various methods of metal exhaust tubulations employs a combination press and solder joint, which completes the seal after the exhaust process by pressing between jaws and heating at the same time to melt the solder. Seam welding can also produce joints which are vacuumatically better than the best glass seals.

Most rectifiers can be greatly simplified when made metallically by having the envelope serve as an anode, thus eliminating the anode seal and allowing excellent cooling. When it is necessary to increase the radiating property of the envelope, this can be done without increasing the general tube size by welding on fins or casting an aluminum radiator directly to the envelope. The cut shows a 60 ampere rectifier of this type, which would be especially effective for highly concentrated gas discharge where rapid heat dissipation will prevent hot-spotting and reverse emission. (*Electronics*, vol. 7, no. 10, October, 1934.)—J. K. J.

FLAKES OF ALUMINUM

THE question of how thin is a flake of aluminum bronze powder is an important one in the paint industry. It has been answered by the Aluminum Research Laboratories, New Kensington, Pennsylvania. In average size, such a flake of powder is not much thicker than the wall of a soap bubble, and it would take more than a hundred of the flakes, one on top of the other, to reach a height equal to the thickness of an ordinary sheet of paper.

The name, "aluminum bronze powder," was applied to the powder of aluminum when it first became commercially available. This is a misnomer because the powder is not a bronze; it has an aluminum purity content of more than 99 per cent. In its use as the pigment portion of paint, it differs from other pigments in that the individual particles are flaky instead of granular. Its effectiveness as a protective covering comes from the fact that the minute metal flakes are impervious to light and moisture. Under the microscope, it is revealed that the flakes overlap in layers in the dried paint film, forming a very thin layer of metal over the painted article. Thick flakes affect the leafing characteristics of the powder and the covering quality of the paint. Therefore it is important that the flake thickness be controlled in the manufacturing processes. To do this there must be some method for their measurement.

To measure flake thickness is difficult, because the aluminum flakes are too small to handle even under the microscope. In the ingenious method which has been devised, the only measuring instruments required are a balance and a common ruler. The remaining equipment used by Assistant Director of Research Junius D.

(Continued on page 140)

SOLVING PRODUCTION PROBLEMS WITH CONVEYERS

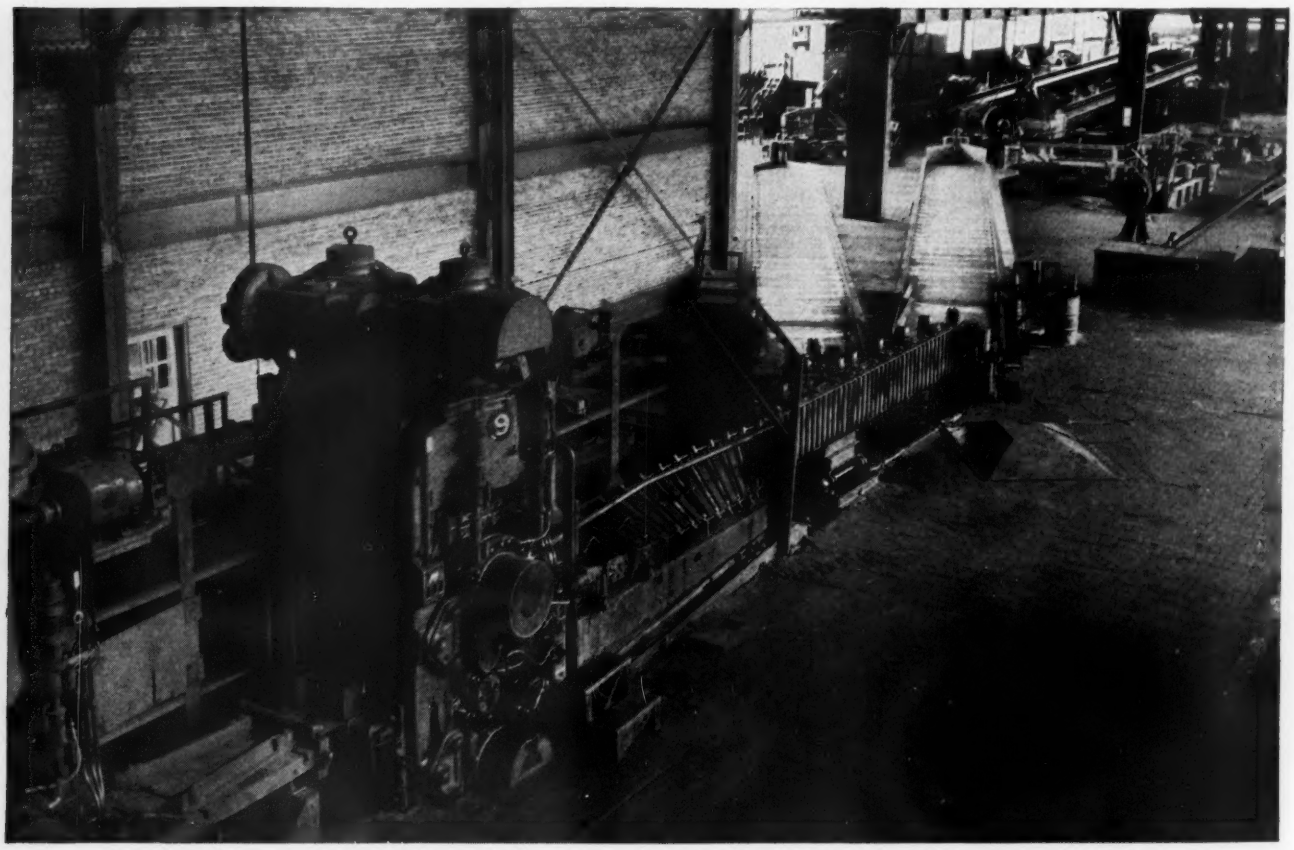
(Continued from page 129)

gauge, that is, not to be coiled, it can be transferred from this long roller table by means of a multiple strand chain conveyer passing between rollers of the roller table. Suitable lugs on the chain pull the sheet off the rollers. These chains extend some distance and serve as a cooling bed for strip that is to be cut to short lengths. At the end of these chains the strip is deposited onto another driven roller table. On this table the strip is conveyed through the flying shear and cut to commercial lengths. A short distance beyond the discharge of the shear the cut sheets are stacked on gravity roller tables, and as stacks are completed, they are conveyed to squaring shears or edging shears, to roller levelers, and to shipping departments, where they are distributed or loaded to cars by means of crane equipment. Rather extensive lines of roller conveyer are used for these connections. Electrically or air operated brakes are included to permit the stopping of stacks as required. Similar lines are also used to permit transfer from one crane bay to another.

When the strip is not of standard commercial gauges, it is too bulky and cumbersome to handle in one long ribbon-like piece. To facilitate handling it is rolled up in a compact coil with a core diameter of about two feet and an outside diameter varying from 32 inches to 48 inches, depending on the mill and coiler capacities in the different mills. Coils vary in weight from 3000 to 10,000 pounds according to the diameter and width of the strip. Strip up to 72 inches wide, in some cases even 84 inches wide, is being rolled in a number of present day mills. As the coiler finishes a coil, it is peeled automatically off the coiler reel and deposited onto a conveyer leading to hot coil storage. While in transit it passes over a section of roller conveyer set on a scale platform where an attendant records the weight and also marks the weight with chalk on the coils. In most cases the coils are deposited onto these conveyers with the cores vertical and are handled from conveyer to storage by means of a crane and magnet. In many cases the coils are tied with heavy wire to facilitate handling while on the conveyer.

Because different types of coilers are used in different mills and because of different crane equipment and piling methods, coils are often discharged from coilers with the core axis horizontal. This requires a different type of conveying means, and instead of magnet pick-up, a single hooked finger is used, the finger being inserted into the core of the coil. In some cases the magnets handle three coils at a time and the finger two at a time.

Where the distance for the strip runout is limited, for some classes of narrow strip a somewhat modified type of equipment is employed from the discharge of the last finishing mill. In such cases the strip is passed through a twist spout, located close to the mill rolls, which turns the strip from a horizontal to a vertical position. These twist spouts are constructed with heavy frames and with two levels of hardened and ground rollers mounted in precision bearings accurately machined and fitted and well lubricated. By means of a continuation of this construction with vertical rollers, a



A ninety degree roller trough by which strip steel is twisted from a horizontal to a vertical position.

power-operated switch is provided to permit two separate discharge locations. Two discharges are required to provide connection to the two coilers, which handle alternate strips.

As each strip is delivered on edge through the pinch rollers at the twist spout discharge, a reciprocating lever and roller causes it to assume a serpentine track upon the apron conveyer onto which it delivers. These apron conveyers, one for each coiler, are about five feet wide and of sufficient length to hold the full strip in its serpentine form. They make the connection from the twist spout to the coilers. These coilers make the coils with the core axis vertical, and deliver them to cooling conveyers leading to coil storage.

When coils are required for pickling in the continuous pickling process, they are removed from the hot coil storage by a crane magnet and placed on a roller storage conveyer leading to the continuous pickle line. These coils thus deposited are automatically removed from this bank storage by a mechanical turn-over device that discharges the coil with its core horizontal onto a troughed roller conveyer. It travels along this to a spring cushioned stop and is there rolled off the conveyer by a mechanical tilting discharge. At this point the coil is in position with the pickling line and in front of the decoiler ready for uncoiling. Strip is handled through continuous pickling in a continuous and endless piece. As a coil is unwound in the decoiler, the tail end is either welded, riveted, or clipped to the outside end of the following coil. At the far end of the pickling tanks the strip is again coiled and the connections separated by shears or torch.

If horizontal coilers are employed, the coil is kicked out onto a skidway connecting a line of troughed roller conveyer. From there it travels to storage or to the cold rolled department. Along its travel it passes over a scale where the weight is checked and recorded. If several crane bays are to be reached, intermediate tilting discharge devices are provided. Braking and stopping mechanism is included at discharge points, at the scale. and at the end of the line.

Lines or troughed roller conveyer are provided in the cold roll department for delivering coils from storage to cold roll mills. Brake equipment and a tilting discharge is used at the end of this conveyer to make delivery to the mill decoiling reel. Although there are several types and methods of continuous strip cold rolling, a typical and satisfactory method consists of a two-stand tandem-coil strip mill with a decoiler at one end and a coiler at the other and with sticker and intermediate feeding rolls and guide equipment to hold strip.

Coiled cold roll strip may again be put into coil storage or delivered direct to edging and stripping shears and for cutting to short lengths. Where sheets are cut to length, they are stacked into piles 18 inches to 24 inches high and carried to finished sheet storage and to shipping departments.

Sheets that are to be normalized are also passed onto conveyers leading to the normalizing furnace. Separate sheets are handled through this continuous furnace, each being carried by a rider sheet. After passing through the furnace, these sheets continue over a live roller conveyer table at the end of which a double deck live roller arrangement separates the normalized sheets from the rider sheet. The normalized sheet passes over the higher level and the rider sheet is pulled off at one side of this double level portion. Rider sheets are returned by a chain conveyer to the receiving end of the furnace and used again.

Conveyers used for hot coil handling may be of different types depending upon the manner in which they are handled at the coilers or by the cranes or on the way they are to be handled in the succeeding operation. For coils with core axis vertical five general types are used:

1. Roller conveyer with horizontal rollers spaced on close centers are often applied advantageously with auxiliary brake devices to stop the coils at the desired locations.
2. Apron conveyers are used consisting of heavy structural bars connecting two strands of chain to form a continuous carrying surface. The chains may be of the roller chain type with rollers spaced between side bars at the joints of links, to reduce friction, or may be of the drag chain type with the chains riding on a supporting trough of antifriction rollers. Separate troughs are used for each strand of chain each with the rollers spaced on centers that are less than the pitch of the chain links. With this construction the coefficient of friction is considerably reduced over the roller chain types thereby requiring less power for equivalent lengths of conveyer.
3. A third type consists of a combination of roller conveyer and chain conveyer, the construction providing two rows of rollers with a single strand of chain supported on a frame between the rows of rollers. To offset the action of hot coils the

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rollers are provided with nitralloy bearings. The chain is provided with suitable pusher lugs to engage the coils through the core and to propel them over the roller surface. Intermittent travel of the chain and suitable discharge of coil onto conveyer permits engagement of pushers with the core.

4. Two strands of heavy drag chain may also serve as a conveying means for coils. As with the apron type conveyer a bed of rollers may be provided to support the chain.
5. Live roller tables with rollers spaced on close centers have also been applied for this purpose. Because of low initial cost, low maintenance, and elimination of power cost, gravity conveyers are frequently used where conditions are suitable. With gravity conveyers both straight and curved directions of travel are equally convenient.

For the handling of coils with the core axis horizontal there are but three types in general use today:

1. Gravity conveyers, having two rows of rollers set at a 10 degree to 12 degree angle from the horizontal to form a vee trough for supporting the coil, are used. Because of the troughed construction they are suitable for straight line travel only.
2. Where conveying around curves is necessary in addition to straight line travel, a gravity conveyer having a bed of near horizontal rollers and a near vertical roller guard has proved very satisfactory. With this construction the conveying surfaces of rollers set at an angle of about 4 degrees off the horizontal with the cross section of the conveyer. A guard rail of rollers vertical to the conveying rollers is necessary to retain the coil on the conveyer. This really is a modification of the above mentioned trough type conveyer. When negotiating curves, the vertical guard is on the inside of the curve.
3. When chain conveyers are applied to handling horizontal coils, the apron type is most suitable. However, it is necessary that the carrying surface be provided with a concave surface or with suitable retaining lugs or cradles to prevent coils from rolling off the conveyer. The chains may be constructed and supported the same as with other apron types.

The reduced cost made possible with a well-planned conveying system soon absorbs the initial expense and the cost of alterations and additional equipment that may be required. Such conveying equipment as briefly referred to in this article has resulted in:

1. Substantial saving in operating cost.
2. Established systematic regularity to processes.
3. Increased efficiency of machines and workmen.
4. Increased production.

Similar results have been obtained in many plants covering every major industry.

The Greeks Had a Letter for It

(Continued from page 127)

The third and final period in the history of the evaluation of π is concerned with the investigation of the real nature of the number. The newer and more powerful methods of analysis available during the third period, together with an increasing interest in mathematics and mathematical physics, resulted in so considerable an amount of work being published that it is entirely outside the scope of this article even to mention all of the more important developments.

Leonard Euler (1707-1783), who marks the transition from the second to the third periods in the history of π, appears to be the first to use the Greek letter π for the incommensurate constant 3.14159 . . . . In 1794 Legendre wrote, "It is probable that the number π is not even contained among the algebraical irrationalities, *i.e.* that it cannot be a root of an algebraical equation with a finite number of terms whose coefficients are rational. But it seems difficult to prove this strictly." But Legendre's quotation was preceded by a proof given in 1761 by Lambert who established the following theorems:

(1) If x is a rational number different fro 0, e^x cannot be a rational number.

(2) If x is a rational number different from 0, tan x cannot be a rational number.

If $\tan x = 1$ when $x = \frac{\pi}{4}$, it follows from these theorems that $\frac{\pi}{4}$ cannot be a rational number. Therefore π cannot be a rational number, and consequently the irrationality of π is demonstrated.

In conclusion, it may prove interesting to outline some of the more exact approximations which have been made, especially during the last century. Richter, for example, gave the value of π to 333 places in 1853. In the same year Rutherford gave the results to 440 places, and W. Shanks gave the results to 505 places and a few months later to 607 places. A new determination of π to 500 places was given by Richter in 1855, and finally in 1873, Shanks gave the value to 707 places.

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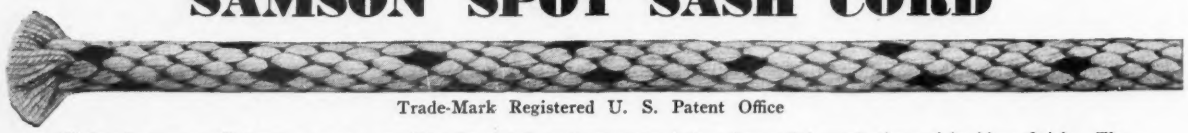

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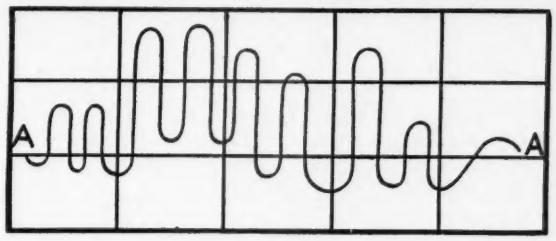

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ENGINEERING DIGEST

(Continued from page 135)

Edwards and Dr. Ralph B. Mason, of the Aluminum Research Laboratories, consisted of a flat-rimmed, shallow, rectangular pan and two strips of glass, each longer than the width of the pan. The pan was filled with water to just above the brim, surface tension keeping it from overflowing. The glass strips were laid on the rim across each end to act as barriers and help "coax" the powder into the desired film, one flake thick.

In a draft-free room, an accurately weighed sample of powder is dusted onto the water surface. Being only partially wet, the flakes float. One of the glass plates is pushed towards the other, sweeping the powder before it, and is then pulled back again. This process of moving one of the plates back and forth is repeated until the powder film formed is uniformly smooth. When the flakes are all touching and are further compressed by the glass plate, the film wrinkles like a piece of cloth.

The barriers are then adjusted just sufficiently to eliminate the wrinkles. By measuring the length and width of the film with a ruler, the area which one gram of powder will cover is calculated. From the area and volume (which is calculated from the density—2.5 grams per cubic centimeter) the thickness is simply calculated. The results of such calculations show the average thickness of the flakes to vary from .00005 to .000012 of an inch with different grades of powder. (*Scientific American,* July, 1934.)—P. Shirley, Jr.

THREE CENTURIES AGO Anthony Van Leeuwenhoek made the first microscope. For over two centuries microscopes were priceless instruments obtainable by only a few. Today Bausch & Lomb manufactures microscopes of unsurpassed quality for every purpose at a price that makes them readily available to Science, Industry and Education. Bausch & Lomb Optical Co., 635 St. Paul Street, Rochester, New York. » »

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RESEARCH IN REVIEW

(Continued from page 133)

ciated with food-borne diseases continues to be one of the major research problems of the department.

The above mentioned subjects indicate the diversity of research projects and interests of the staff, but is far from complete. Other projects are found in the study of various biological and biochemical phenomena associated with the manifold activities of living things. Particular emphasis is placed on the health aspects of these problems.

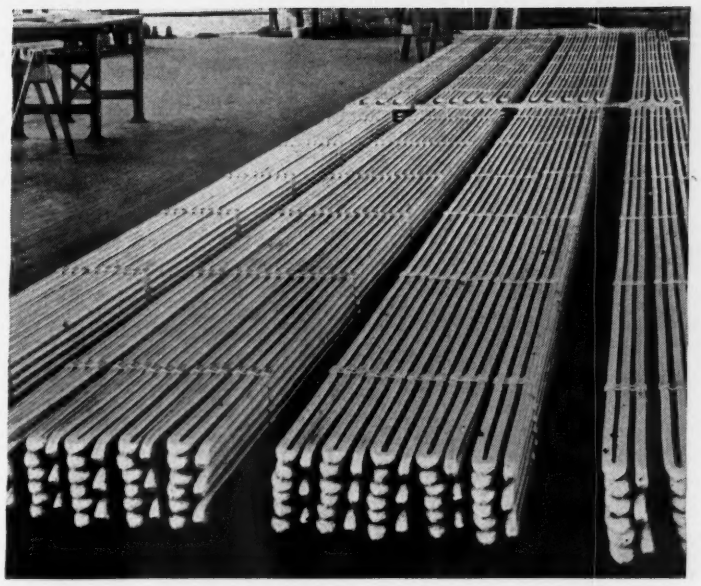
COURSE XI — Sanitary Engineering

PROFESSOR CAMP has recently instituted experimental and theoretical studies of the clarification of water and sewage by sedimentation. He has developed an instrument for the measurement of the magnitude and distribution of the settling velocities of the particles of suspended matter in a liquid. Studies have already been made of the distribution of velocities of the liquid in model settling tanks, as well as of the hydraulics of dispersion walls as a means for controlling the distribution of flow into and from settling basins.

Professor Camp has also begun experimental studies on the hydraulics of "round-the-end" baffled coagulation basins with a view to increasing the available knowledge regarding head losses in such basins.

In addition, Professor Camp and his students are making experimental and theoretical studies of the principles of clarification of water by filtration through sand in an effort to develop a completely rational "theory of filtration." An experimental filter, consisting of glass tubing built up vertically with a number of pieces which are fastened together at the joints by means of steel flanges cemented to the glass, is being used at the Providence Water Purification Plant for these studies. This unit is charged with sand and is used to remove iron floc from water. Measurements are being made of head losses through the various layers of sand, of removal by these layers, of the clogging of the sand, and of other pertinent data. Furthermore, Professor Camp is making experimental studies of porous plates for use in filter bottoms for rapid filtration of water through sand. A new type of bottom is being evolved which has many advantages over other types now in use.

A method of solving hydraulic problems relating to municipal water distribution networks has been developed jointly by Professor Camp and by Professor Hazen of the Electrical Engineering Department. This method employs an electrical calculation board similar to the M. I. T. Electric Network Analyzer. In the water network analyzer an analogy is made between the flow of water through pipes and the flow of direct current through wires in such a way that an electrical model of the water distribution system may be set up upon the calculating board.



SEVEN HUNDRED WELDS—were needed to make this assembly of aluminum piping.

New Metals Emphasize Desirability of Jointless Design

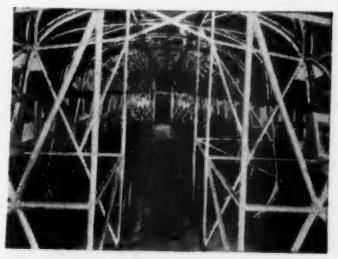
Welding Preferred Method for Fabricating Jointless Designs from New Materials

By H. E. ROCKEFELLER*

Welding is an important aid in securing the full benefit of the newer light weight alloys, corrosion- and stain-resistant steels and other ferrous and non-ferrous metals. Jointless welded designs in these new metals make the finished product attractive in appearance, efficient and economical to use and enable it to be priced salably.

In All Industries

Fabrication by welding can be undertaken without heavy capital expenditures and carried out at low cost. Welding is used in every industry for maintenance, for construction and for the fabrication of many products. The welding of mechanical refrigerators and gas ranges is typical of its production applications. Other typical applications include welding of chromium steel for resistance to sea water corrosion on seaplane pontoons, welding aluminum fuel tanks for airplanes, welding of the frame work of alloy steel on the new high speed railroad trains, welding of stainless steel beer barrels and innumerable other familiar products.



HERE'S HOW—the framework of the light weight, streamlined rail cars for high speed is Linde-welded from chrome-molybdenum steel tubing.

Welding is Simple Production Tool

Welding is the preferred method of fabricating almost every design in modern metals. Jointless welding can be done rapidly with a minimum of preparation of the pieces to be joined. Under procedure control providing jigs for positioning pieces, production can be as rapid and as free from rejections as any highly developed factory process. From the plant equipment standpoint it is easy to adopt welding. From the personnel standpoint the welding technique is quickly acquired through instruction by competent engineers.

For Jointless Strength and Safety

Products fabricated by welding are jointless, leakproof, permanent and safe. Improved methods of testing make it possible to tell exactly what stresses or loads a jointless welded assembly can take. Metals of different compositions, providing the most suitable material for the service it is to perform, can be welded into sound unified assemblies forever free from any of the losses which occur from joint failures.

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To utilize the new alloys and metals fully, the advice of competent engineers in welded design is advisable. The Linde Air Products Company, a unit of Union Carbide and Carbon Corporation, has for many years specialized in the development of new ways to use oxy-acetylene welding. Linde Engineers will gladly consult with you without obligation, and help you use welding and

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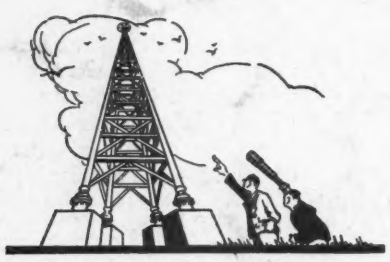
* Engineer, Development Section, The Linde Air Products Company, Unit of Union Carbide and Carbon Corporation.

G-E *Campus News*



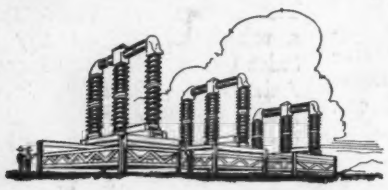
TALKING TOWER

The highest self-supporting tower in the United States used as an aerial is now in operation at General Electric's radio station KOA at Denver. The tower, standing 470 feet high, is a departure from the customary type of radio antenna, where copper wires are stretched in "clothesline" fashion between two towers. It will act as a vertical radiator of radio waves.

With the "clothesline" antenna, a large part of the electric energy released flows directly upward and is lost in space, whereas with the new type of radiator at KOA, a larger quantity of the broadcast waves radiate parallel to the earth's surface.

Slender compared with others of its kind, the tower is but 35 feet square at the base and tapers to two feet square at the top. It will withstand a wind of 125 miles an hour, and its 50-ton weight is carried by four huge porcelain "eggs," which insulate it from the ground.

The new antenna was installed this summer in connection with a new 50,000-watt General Electric radio transmitter.



RECORD-BREAKING BREAKERS

The 287,500-volt transmission lines from Boulder Dam to Los Angeles will be protected by eight General Electric super-speed impulse oil circuit breakers—having higher ratings than any other circuit breakers so far developed. In appearance, the breakers are completely different from previous breakers. They resemble great "E's" lying on their faces. They will be used at a higher voltage than any other breaker. They are rated to interrupt the circuit in slightly more than one-third the time required by previous high-voltage breakers. The most startling fact about the breakers, however, is that the complete units will weigh less than the oil which would be required by a unit of conventional design.

The impulse type of breaker, in which a piston drives streams of oil into the arc paths when the contacts separate, was developed by General Electric engineers at first for electric railway service, where it has proved highly successful.

COFFIN FELLOWSHIPS

Eight technical graduate students resumed their studies this year with the reassuring thought that a good part of their expenses will be taken care of by fellowships granted them by the Charles A. Coffin Foundation, which was established by General Electric in honor of its first president.

The fellowships were granted to: Russell Charles Buehl, Brooklyn Polytechnic Institute, '32, M. S. at Massachusetts Institute of Technology, to study at M.I.T.; Milton G. White, U. of California, '31, to continue study there; Bascom Henry Caldwell, Jr., U. of Texas, '30, to study at Yale; Thomas Benjamin Jones, Johns Hopkins, '33, to continue study there; Sidney Kaufman, Cornell, '30, to continue study there; Leonard Trainer Pockman, Stanford, '33, to continue study there; Arnold Byron Steiner, Stanford, '33, to continue study there; and Clark C. Stephenson, U. of Kansas, '32, to study at the U. of California. All the fellowship winners are carrying on investigations in electrical phenomena; two are specializing in high-voltage research.

In addition to these fellowships, the Charles A. Coffin Foundation annually grants awards for the highest achievements in the utilities and electric railway fields, and honors G-E employees who have made outstanding contributions to the progress of the Company and the industry.

96-85DH

GENERAL ELECTRIC